

Full Wafer Imaging Budget Verification and Litho Performance Optimization

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Outline

- *Introduction*
- Imaging budget verification NXE:3100
- NXE:3300 imaging capability
- Photoresist progress
- Conclusions

The NXE:3100 key specifications



- Imaging
 - Resolution 27nm
 - NA=0.25
 - $\sigma=0.8$
- Overlay
 - DCO=4.0 nm
 - MMO=7.0 nm
- Productivity
 - 60wph
 - 10mJ/cm² resist

Outline

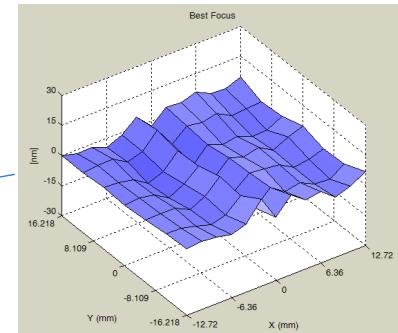
- Introduction
- *Imaging budget verification NXE:3100*
- NXE:3300 imaging capability
- Photoresist progress
- Conclusions

Imaging budget verification with the NXE:3100

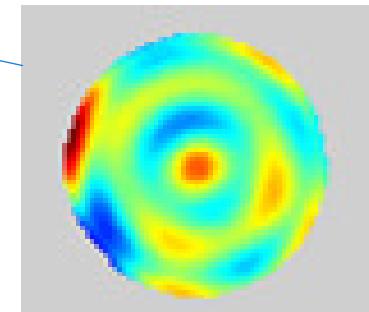
- Exposure conditions
 - NA=0.25, $\sigma=0.8$ conventional illumination
- Test features
 - 27nm isolated lines, 189nm pitch
 - 27nm dense lines, 54nm pitch
 - 27nm twobar
- Test metrics
 - Exposure latitude (Contrast)
 - Depth of Focus
 - CDU across-slit, across-field, full wafer
 - Asymmetry (L1-L2)

Sub-system setup and verification tests performed

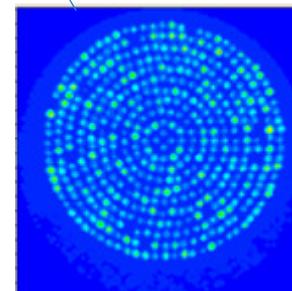
<i>Test</i>	<i>Description</i>	<i>Sampling</i>
FOCAL	IPD, AST	Field
FUV	Focus uniformity verification	Wafer
ILIAS	on-board actinic wavefront metrology	Slit
Pupilias	on-board actinic pupil metrology	Slit
SAMOS	Flare	Slit
Zeiss	Apodization	Slit
Various	POB, stages dynamics	Wafer



FOCAL



ILIAS



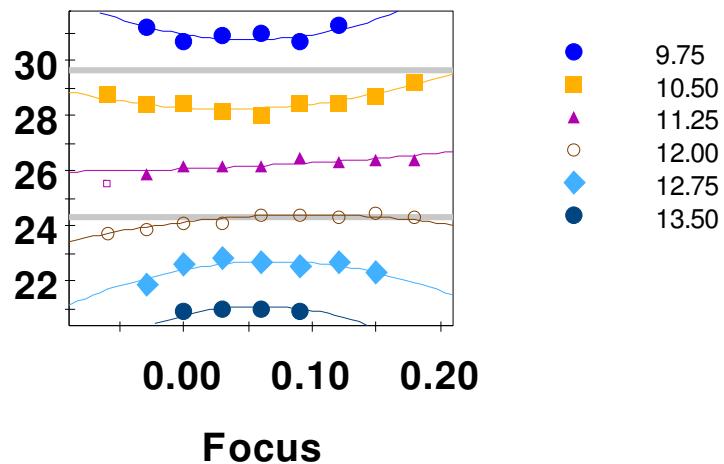
PUPILLIAS



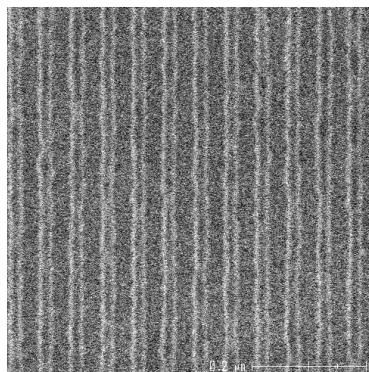
ASML

27nm process window results with the NXE:3100

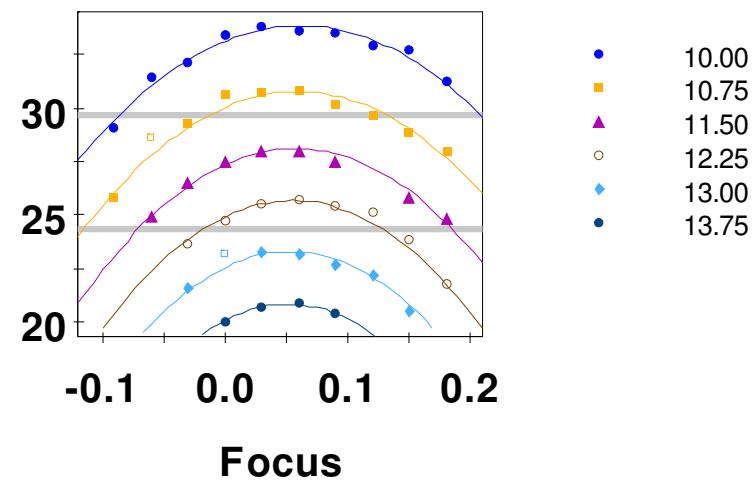
27nm DL 1:1 (SEVR140 on Si)



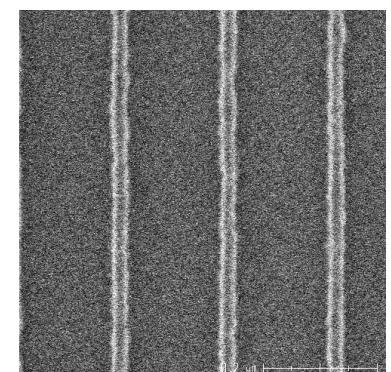
$E_{size} = 11.0 \text{ mJ}$
 $\text{DoF} = 240\text{nm}$
 $\text{EL} = 18\%$
 $\text{LWR} = 5.5\text{nm}$



27nm IL 1:6 (SEVR140 on UL)



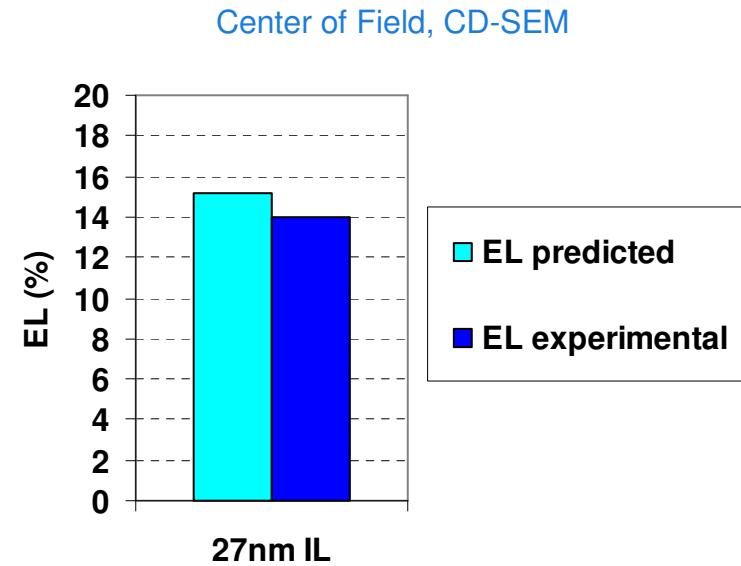
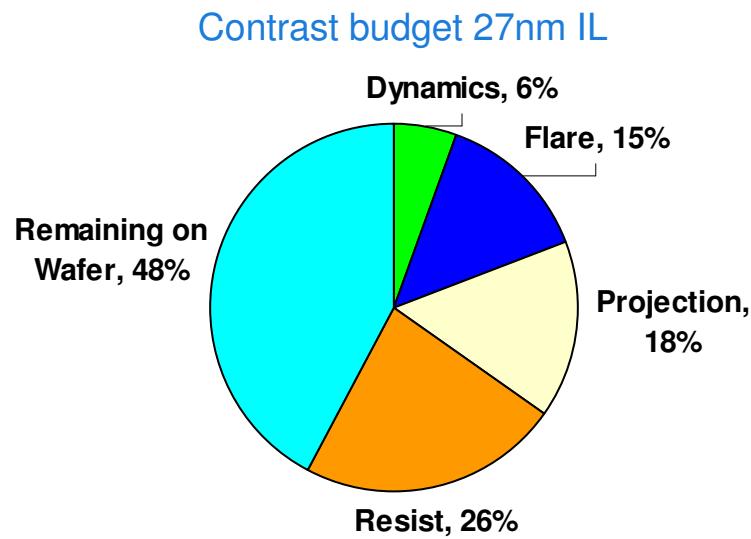
$E_{size} = 11.8 \text{ mJ}$
 $\text{DoF} = 240\text{nm}$
 $\text{EL} = 14\%$
 $\text{LWR} = 4.8\text{nm}$



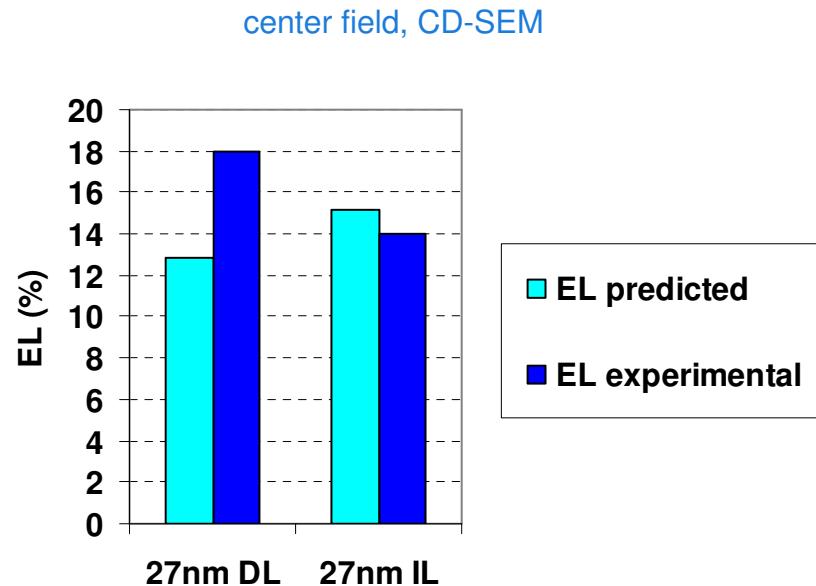
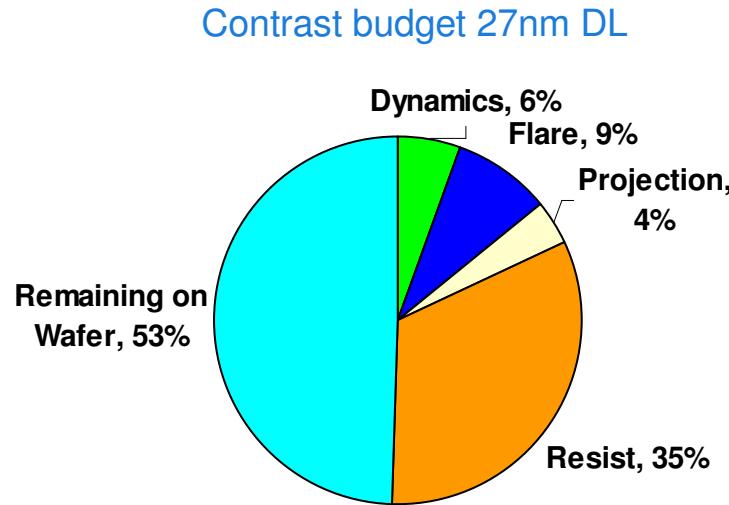
Contrast budget verification 27nm isolated lines

Steps taken:

1. Aerial image EL modeled for 55nm absorber, perfect system 31%
2. Aerial image EL modeled including system contributors 25%
3. Resist EL modeled (resist model calibrated on ADT) 15%
4. Experimental EL compared to modeled EL



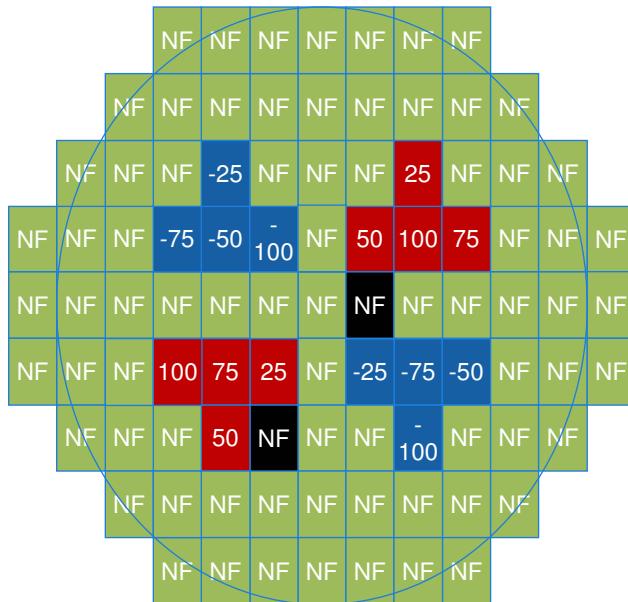
Contrast budget verification 27nm dense lines



- 27nm DL experimental EL higher than predicted
 - Imperfect resist model/ CD SEM calibration suspected
 - Resist profile analysis ongoing to improve

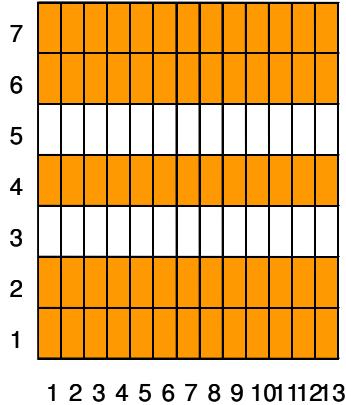
Full wafer CD budget verification wafer and module layout used in the ASML test procedure

Wafer exposure layout



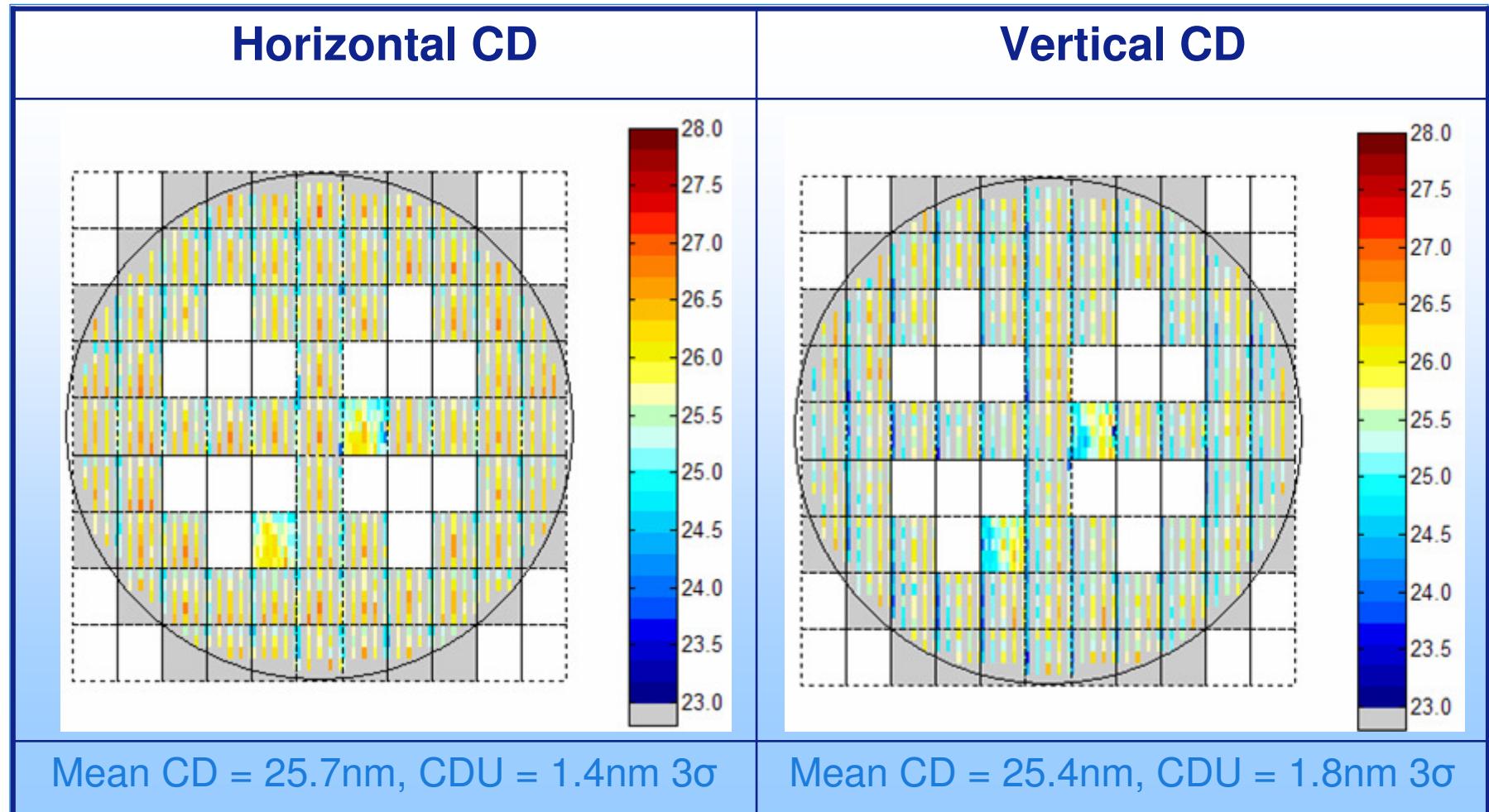
Nominal (Green) and Off Focus field
(+Red/ - Blue), two NF fields (Black)
measured at high density

Module layout



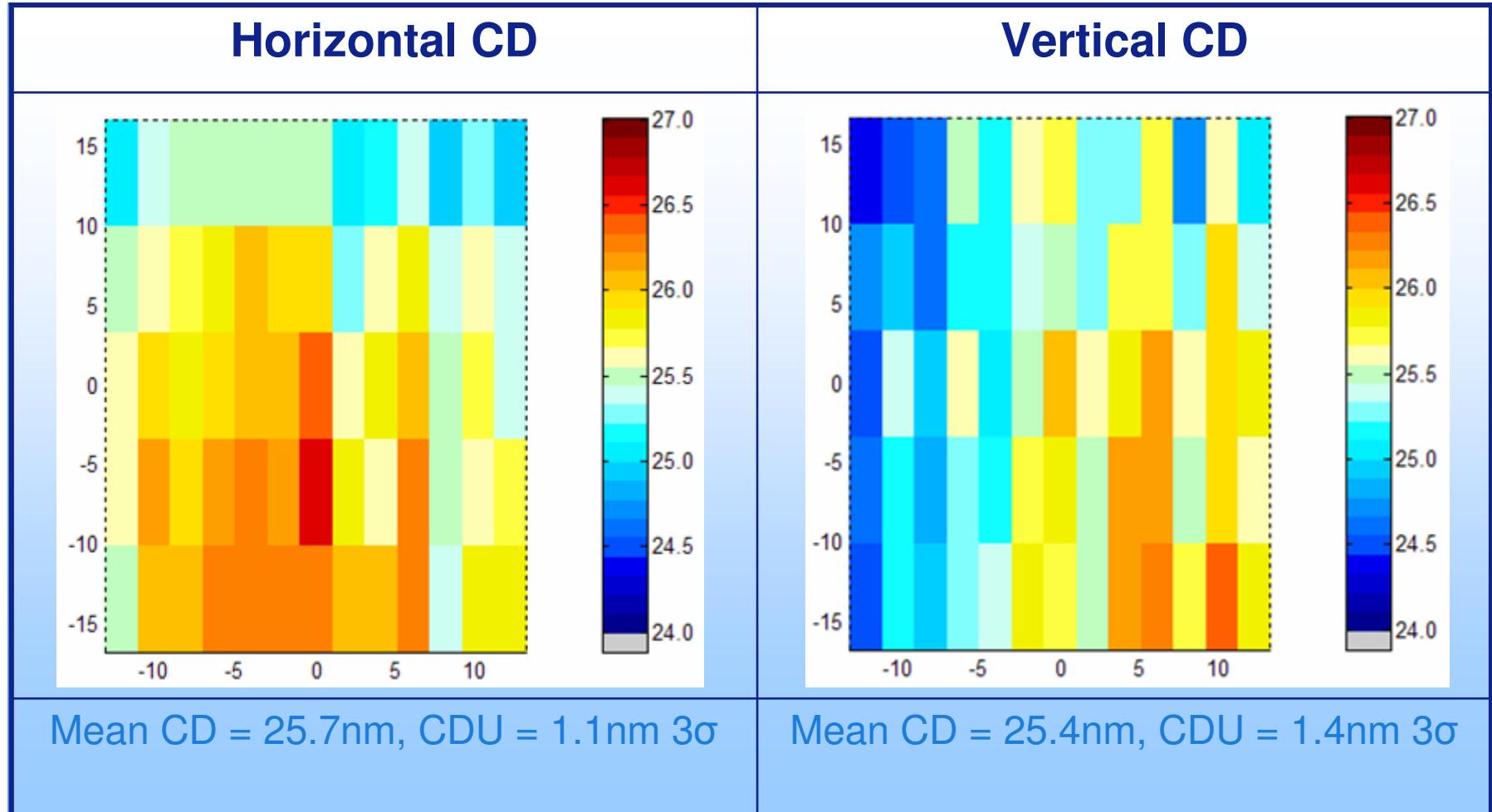
26x33mm exposure field
13x5 (orange) modules are
measured

Full wafer CDU 27nm isolated lines



26x33mm fields, only NF fields shown
After Reticle, Shadowing and Process correction

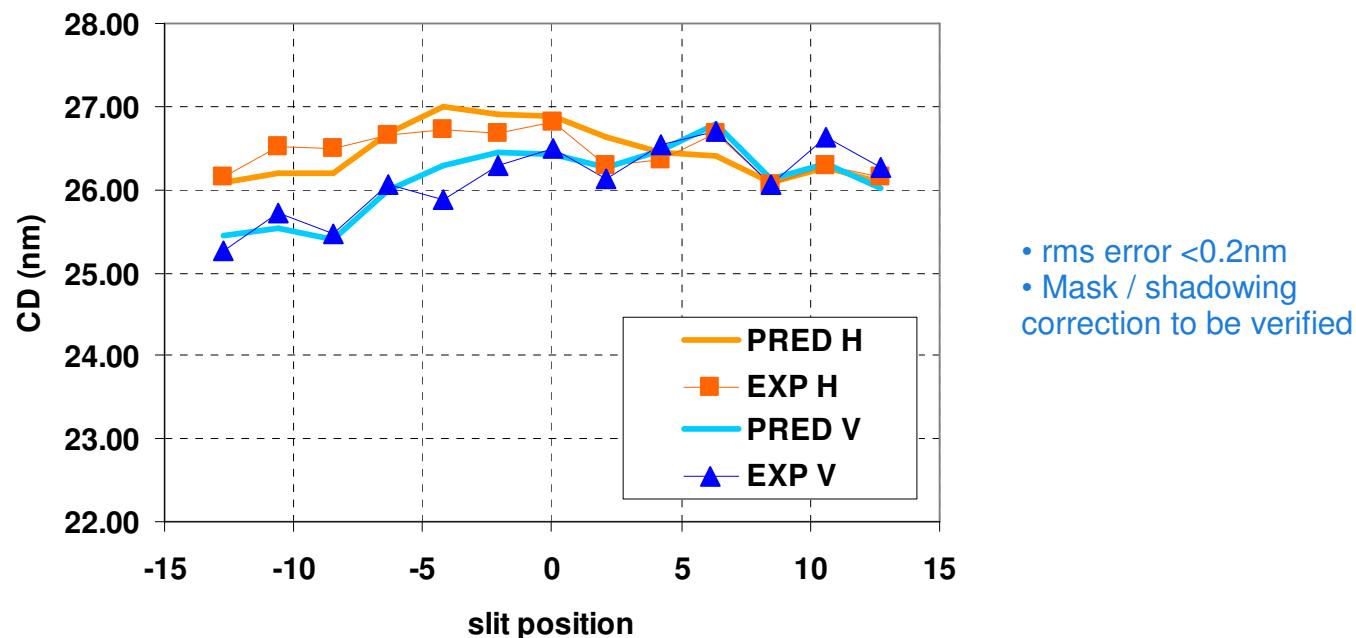
Across Field CDU 27nm isolated lines



26x33mm fields
After Reticle, Shadowing Correction

Across slit CDU 27nm isolated lines

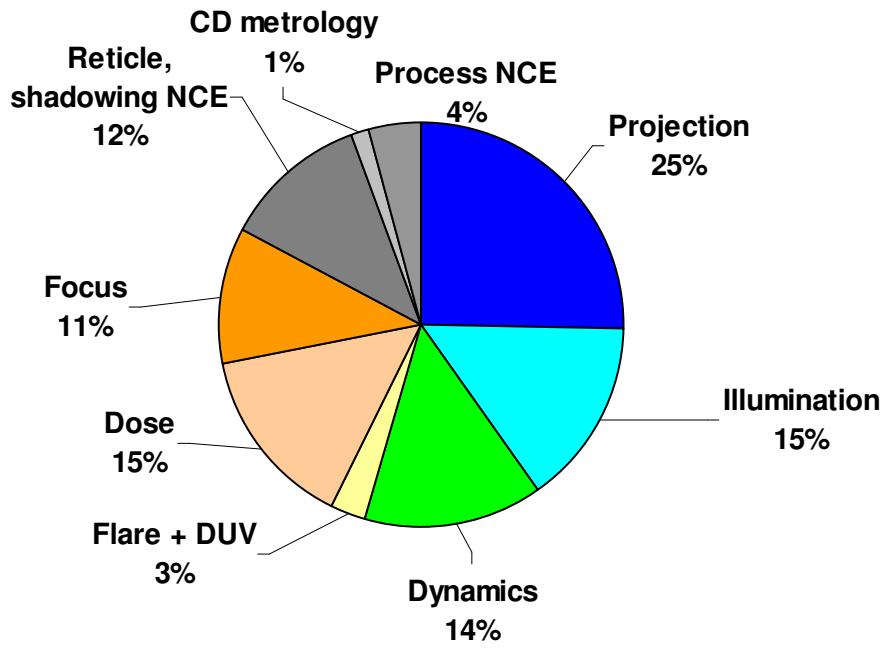
- Good match between predictions and experiment
 - Predictions based on measured source pupil, lens aberrations, apodization, slit uniformity and dynamics



27nm Isolated lines CD budget verification

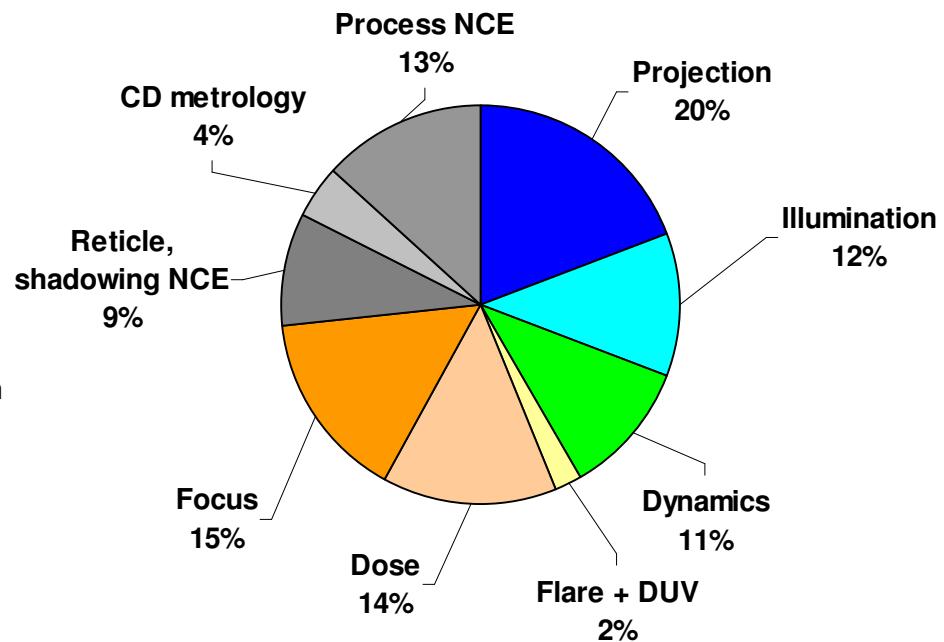
CDU Across field (3σ , V)

- Experiment 1.5 nm
- Prediction 1.5 nm

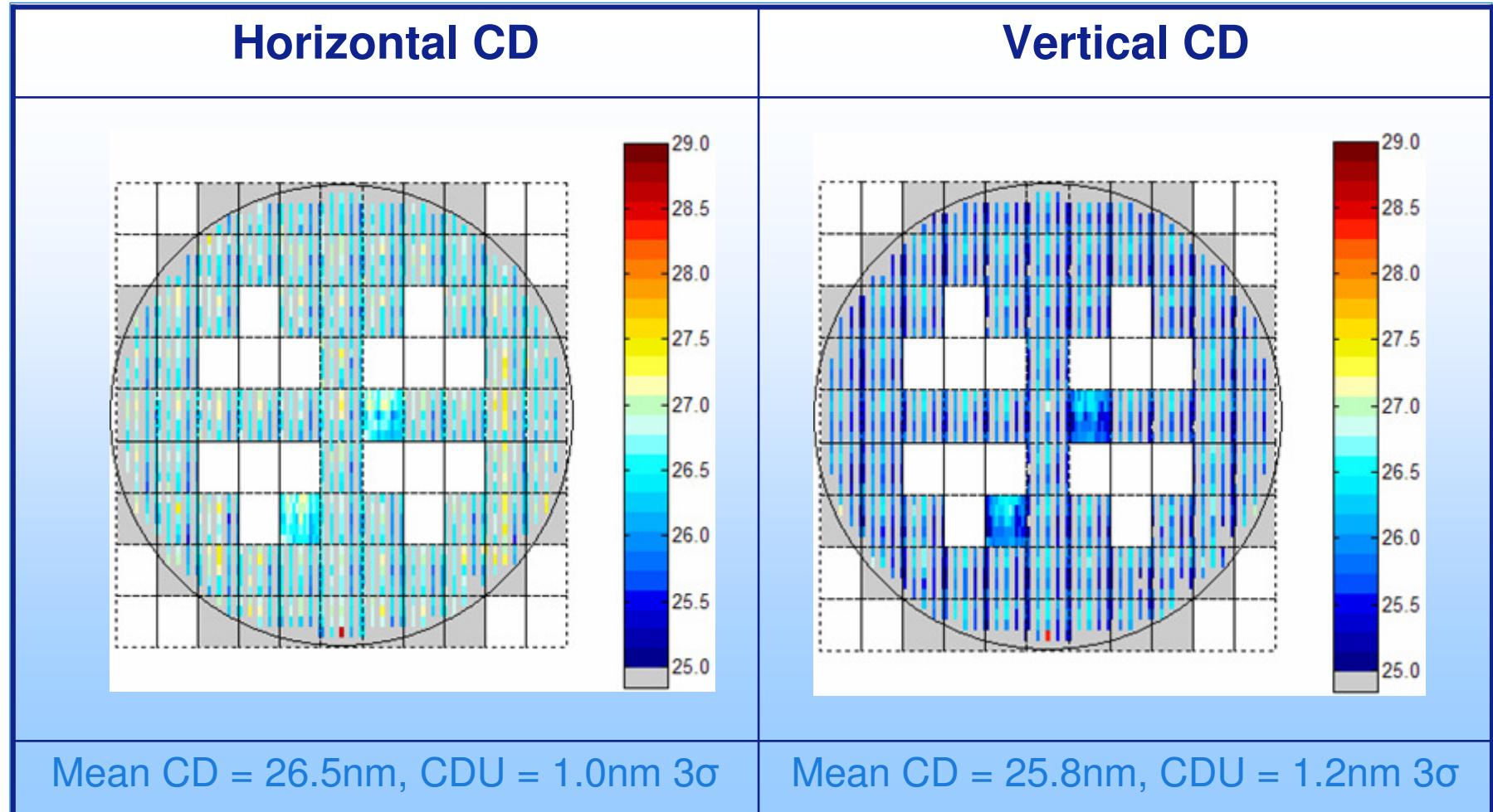


CDU Full Wafer (3σ , V)

- Experiment 1.8 nm,
- Prediction 1.8 nm

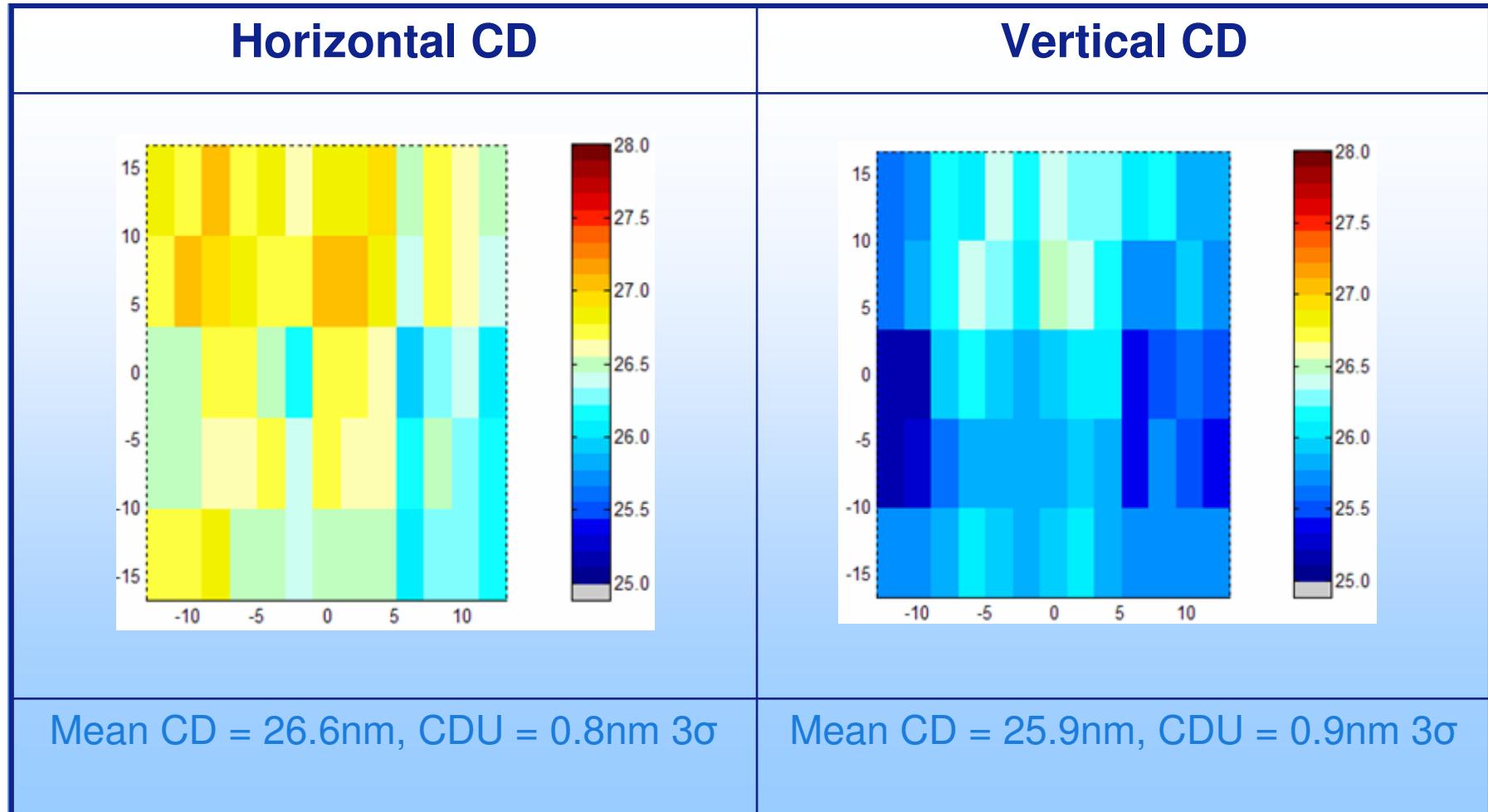


Full wafer CDU 27nm dense lines



26x33mm fields, only NF fields shown
After Reticle, Shadowing and Process correction

Across Field CDU 27nm dense lines

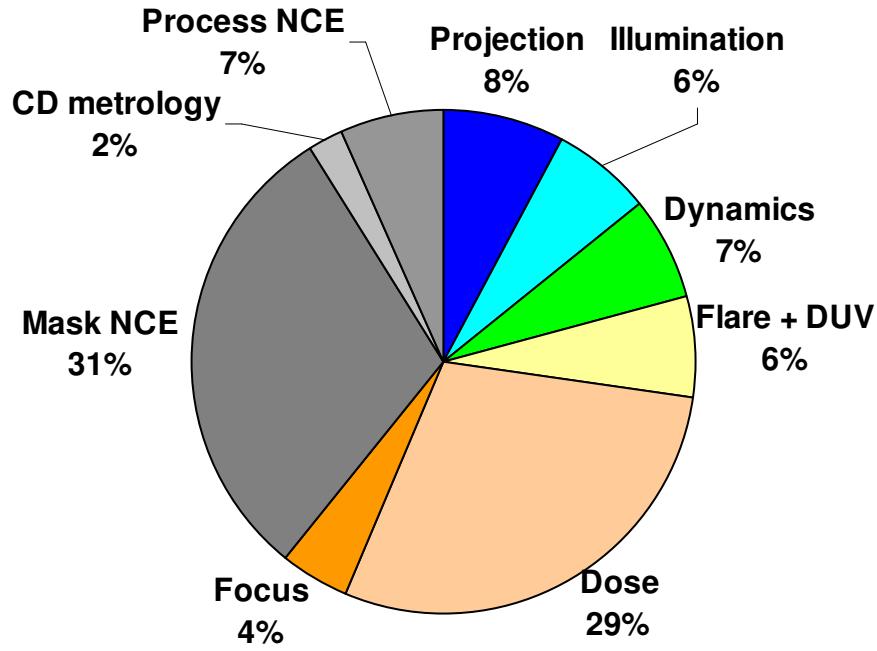


26x33mm fields
After Reticle, Shadowing Error Correction

27nm dense lines CD budget verification

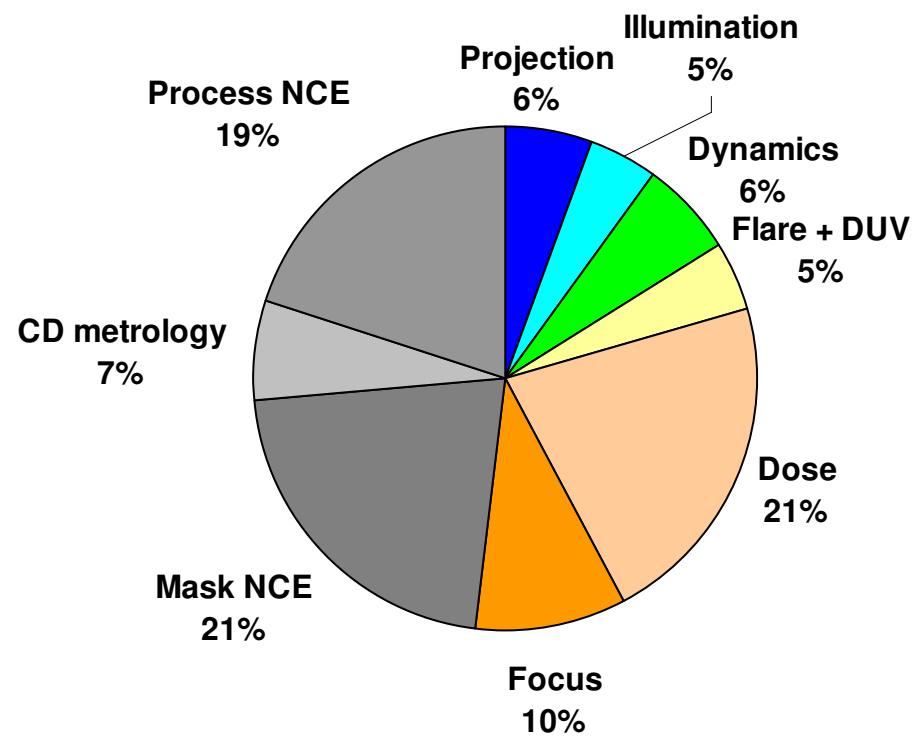
CDU Across field (V)

- Experiment 0.9nm
- Prediction 1.0nm



CDU Full Wafer (V)

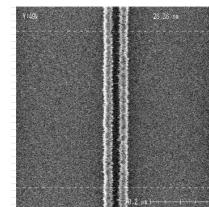
- Experiment 1.2nm
- Prediction 1.2nm



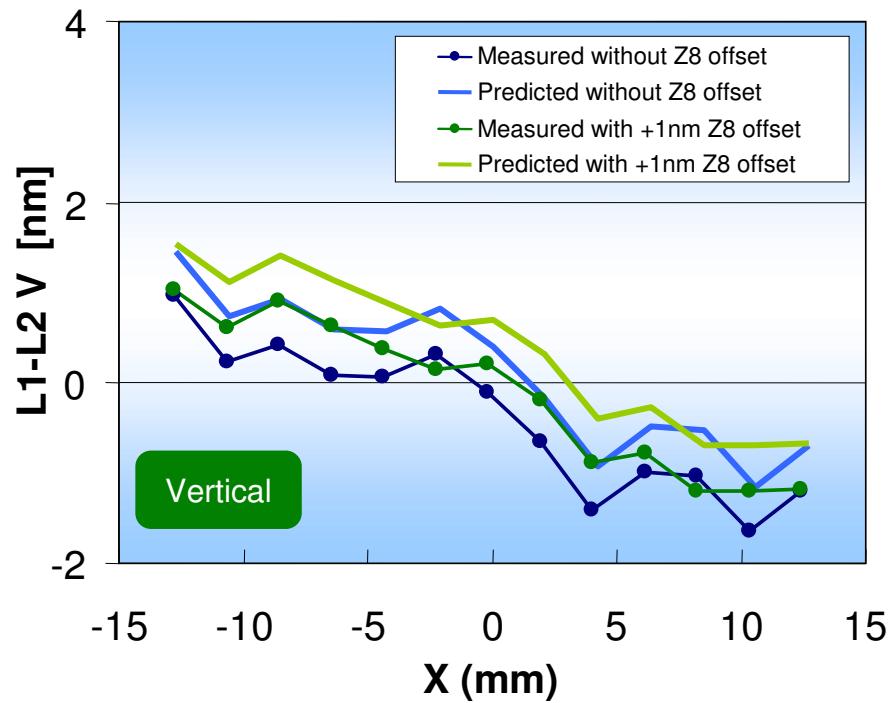
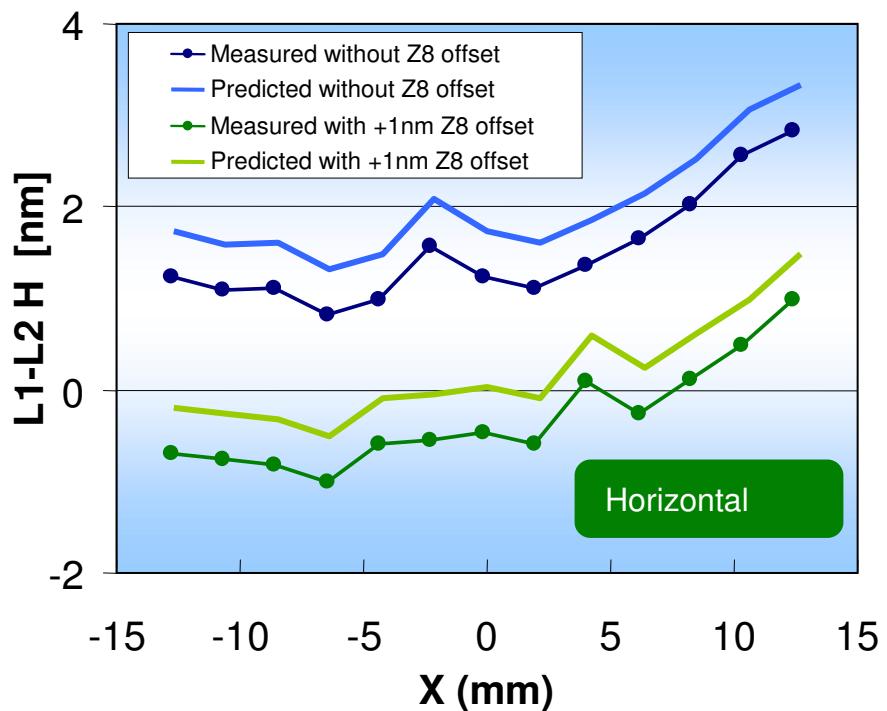
Twoobar optimization shows control of coma aberrations

- L1-L2 sensitive to coma aberrations
 - Z8 impacts horizontal L1-L2

L1 L2



27nm lines
54nm pitch

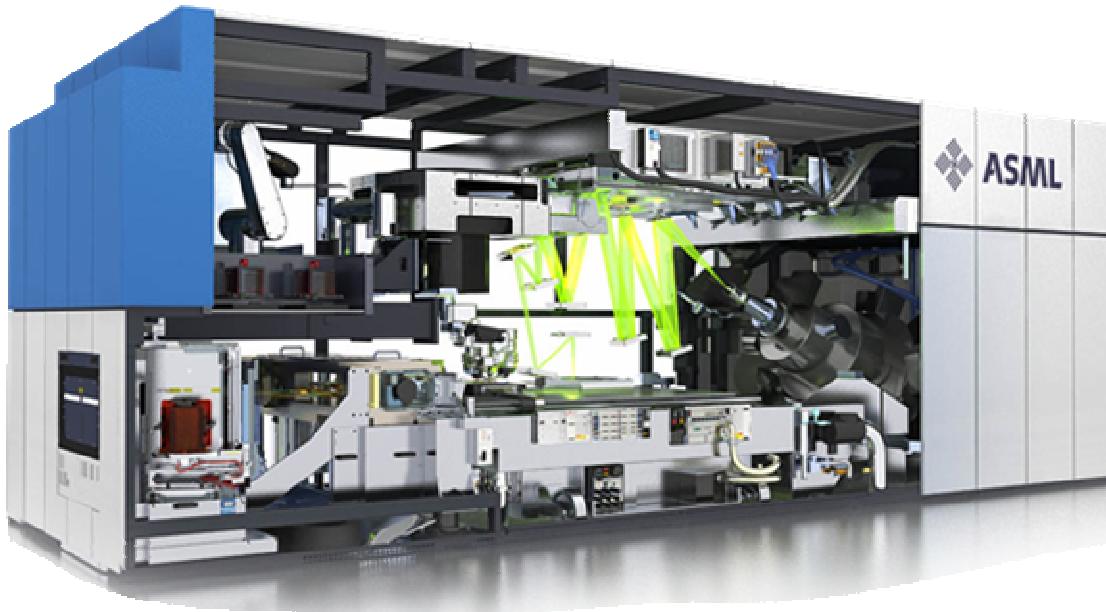


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NXE:3300B exposure system

2nd generation of NXE platform

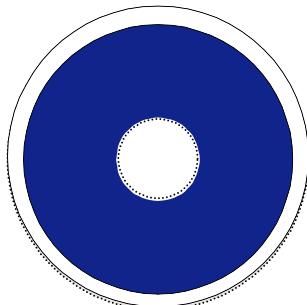


Specifications

- Imaging
 - NA = 0.33
 - $\sigma=0.2\text{-}0.9 / \text{OAI}$
 - Resolution 22 nm
18nm with OAI
- Overlay
 - DCO 3.0nm
 - MMO 5.0nm
- Productivity
 - 125 wph
 - 15 mJ/cm² resist

NXE:3300 full transmission illumination settings

standard: conventional setting

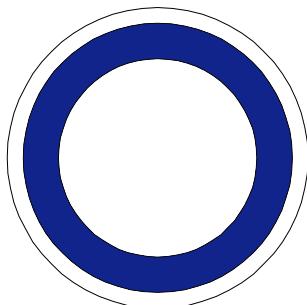


$NA=0.33$

Conventional

$\sigma=0.20-0.90$

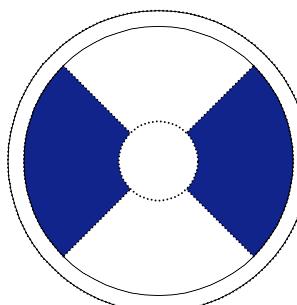
optional: 6 off-axis settings



$NA=0.33$

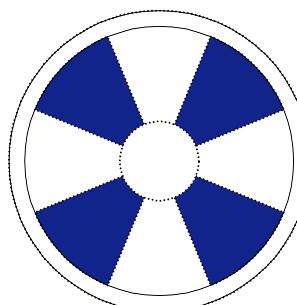
Annular

$\sigma=0.65-0.90$



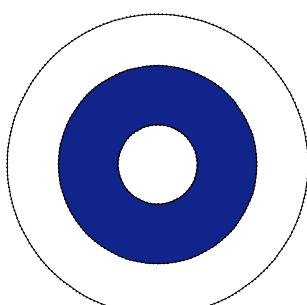
Low sigma

$\sigma=0.20-0.65$



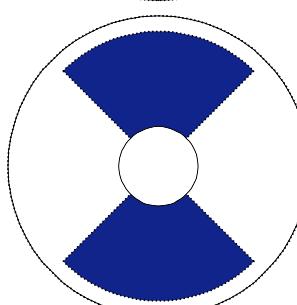
Dipole-90-x/y

$\sigma=0.2-0.9$



Quasar 45

$\sigma=0.2-0.9$

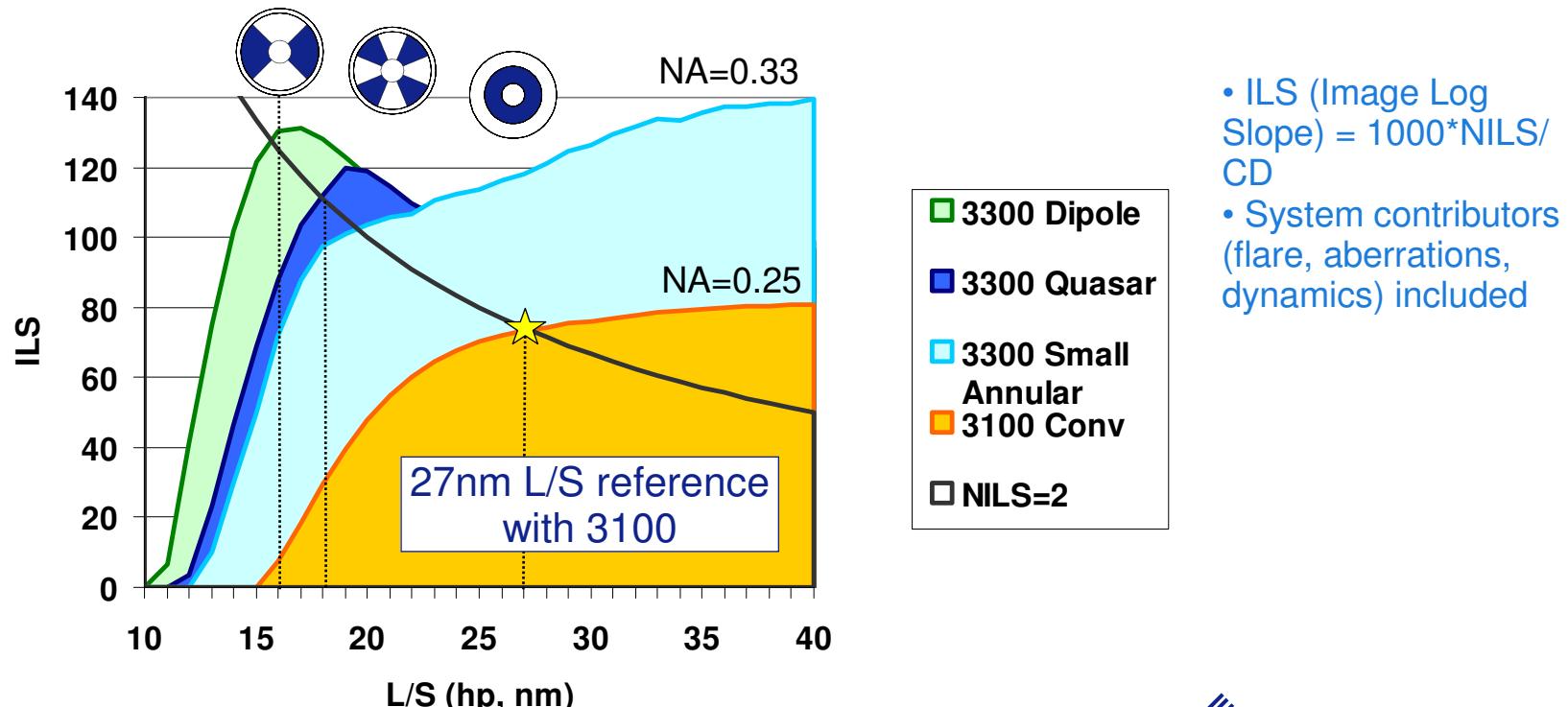


C-Quad 45

$\sigma=0.2-0.9$

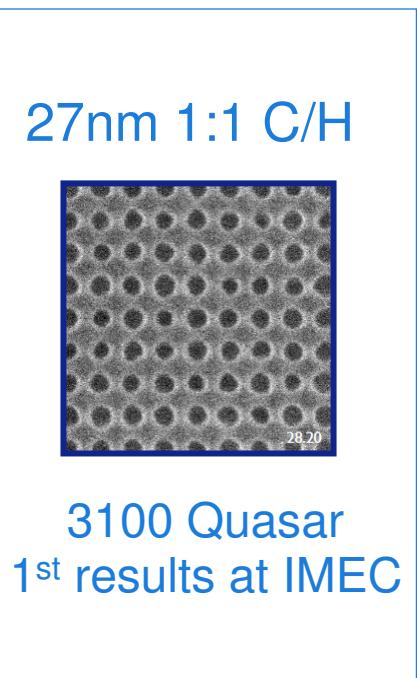
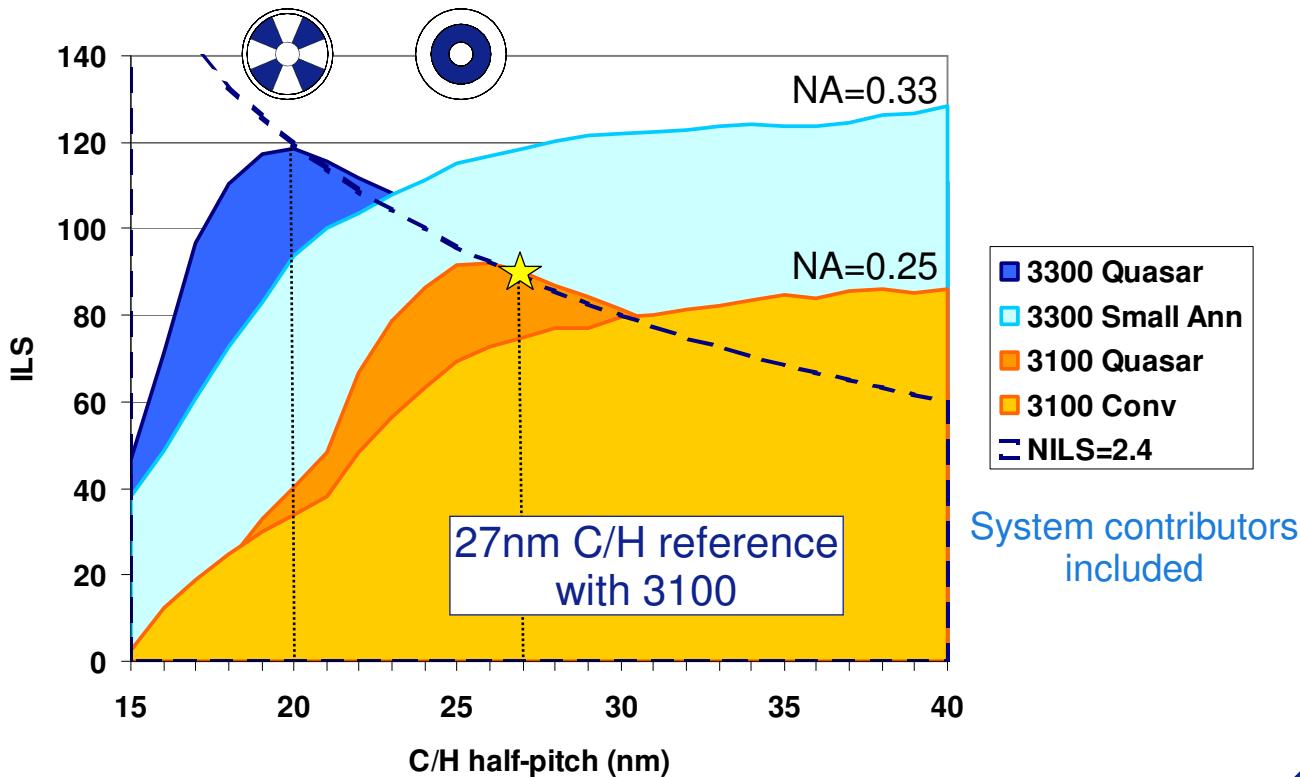
High contrast for 16nm L/S with Dipole90

- Based on 27nm L/S reference with the NXE:3100 (NILS=2)
- 16nm L/S with Dipole90, 18nm L/S with Quasar45
- >22nm L/S best with Small Annular



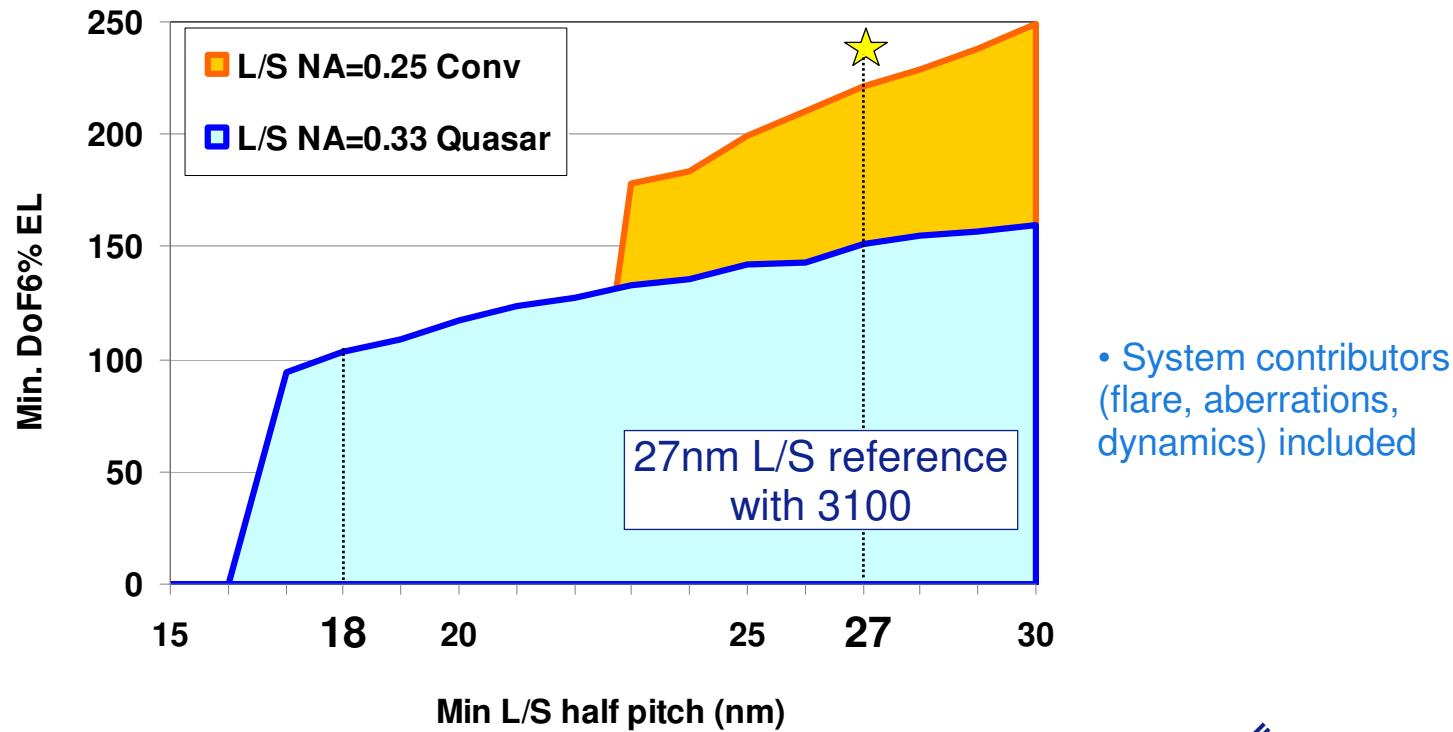
High contrast for 20nm C/H with Quasar

- Based on 27nm C/H reference with the NXE:3100 (NILS=2.4)
- 20nm C/H with NA=0.33 and Quasar45
- >22nm C/H best with NA=0.33 and Small Annular



18nm L/S DoF more than 100nm for NXE:3300

- Based on 240nm min. DoF for 27nm L/S through pitch (3100)
- 18nm L/S DoF more than 100nm over full pitch range
 - Pitches 36-126nm, With OPC, no SRAF, 3D mask, 7nm resist blur

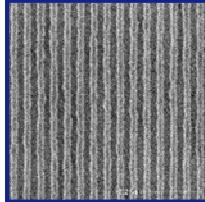
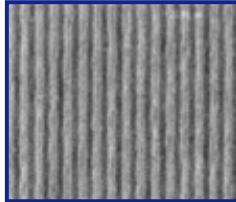
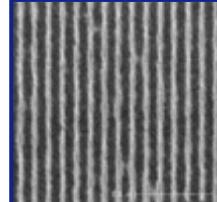
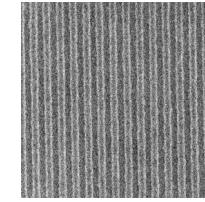
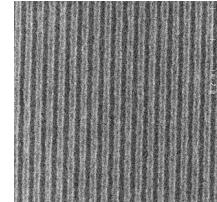
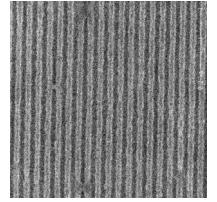


- System contributors (flare, aberrations, dynamics) included

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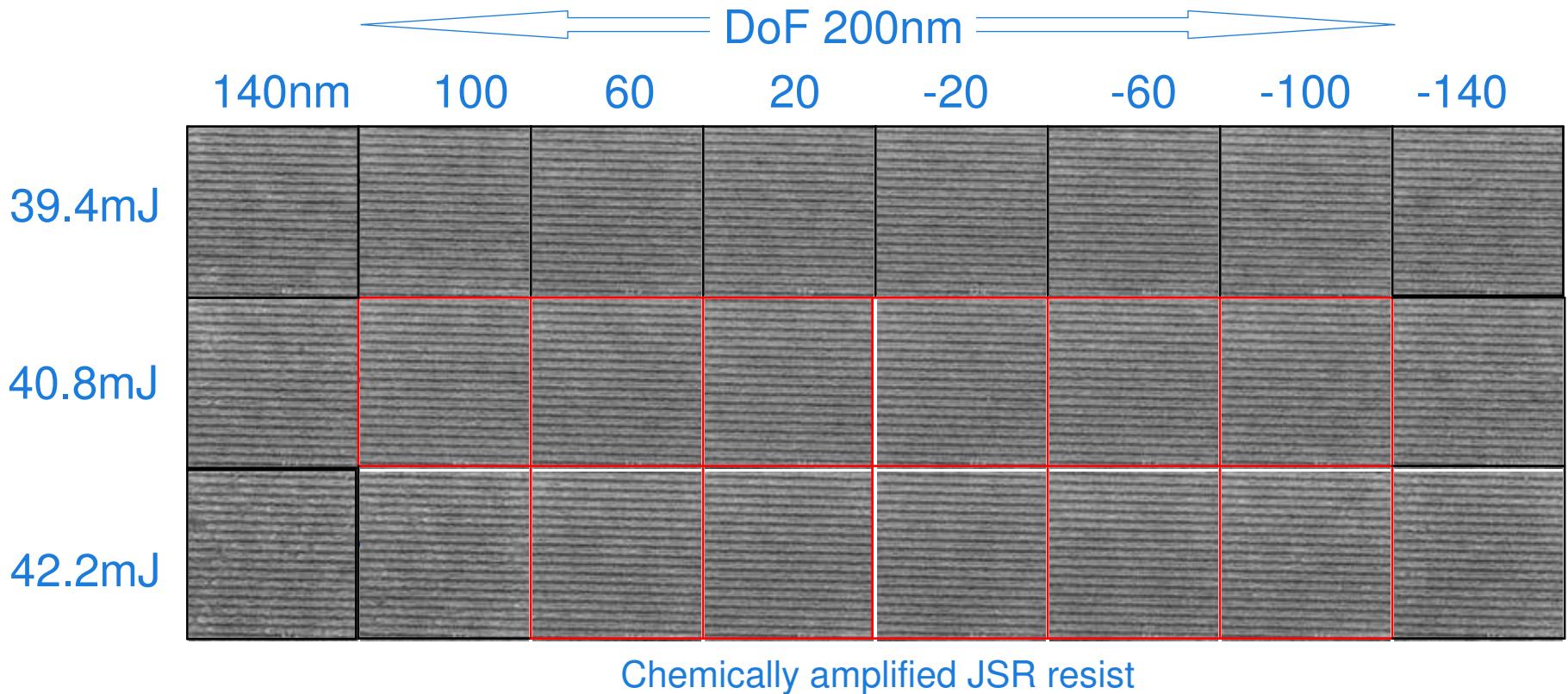
Resist progress towards 22 and 18nm

L/S 1:1	22 nm	20 nm	18 nm	17nm
Dose target	15 mJ/cm ²		15 mJ/cm ²	
NXE:3100 NA=0.25 Dipole (1Q11)	 SEVR140: 12mJ, 12% EL, 200nm DoF	 SEVR140 14mJ	 Inpria 70mJ	
LBNL MET NA=0.30 Dipole (3Q11)	 FujiFilm CA Resist 19mJ, 3.7nm LWR		 JSR Resist 40mJ (CA)	 JSR Resist 40mJ (CA)

* GLOBAL FOUNDRIES data obtained using the SEMATECH LBNL MET



18nm 1:1 L/S process window with CA resist



Good DoF, however LWR, EL and E_{size} need significant improvement

GLOBALFOUNDRIES data obtained using the SEMATECH LBNL MET



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Conclusions

- Full wafer imaging budgets with the NXE:3100 verified
 - 27nm L/S CDU: 0.9nm across-field, 1.2nm full wafer (3σ)
 - Good predictability of the CD slit fingerprints
- NXE:3300 expected performance
 - 16nm L/S and 20nm C/H imaging capability
 - More than 100nm DoF for 18nm L/S
- Good progress chemically amplified resists
 - 18nm L/S ‘process windows’, 17nm L/S resolution

Acknowledgements

- The work presented today, is the result of hard work and dedication of teams at ASML and many technology partners worldwide including our customers
- ASML is grateful for the support by the Dutch Government of the EAGLE and EXEPT projects, as well as the MEDEA+ and CATRENE organizations of the European Union
- Special thanks to:
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 - Eric Hendrickx, IMEC